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Project AG-1729-A

CORNELL AERONAUTICAL LABORATORY, INC.

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RE-ENTRY RADIATION AND AIR FLOW

Contract No. NASr-119

EIGHTH QUARTERLY REPORT

1 March 1964 to 31 May 1964

This work is directed toward the determination of the non-equilibrium flow field and the optical radiation around a vehicle traveling at high speed and high altitude.

Chemical Rates

The extension of known dissociation rates to temperatures associated with superorbital reentry requires a knowledge of the coupling of dissociation with the internal motions of the molecule, i.e., the relative dissociation rates for molecules with different degrees of internal excitation. There are two aspects to this problem that are being investigated under the present contract. The first concerns the calculation of the rate of vibrational excitation using time-dependent wave functions. This investigation was described briefly in the last progress report, and is discussed as Item I below. The second has to do with the non-Boltzmann quasi-equilibrium distribution of vibrational energy during the dissociation

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process. This distribution has a direct effect on the dissociation rate, and an experiment to measure the distribution during dissociation was discussed in the last progress report. The work performed during the last quarter is summarized as Item II.

I. Vibrational Relaxation. The last progress report contained a discussion of the use of time-dependent vibrational wave-functions to describe the vibrational transition of a molecule which collides with an incident particle. The first-order treatment gives a closed form expression for the transition probabilities and these were shown graphically to agree well with numerical results of Rapp and Sharp[1] in the range of collision velocities up to $\sim 6 \times 10^5$ cm/sec (2.5 ev) for the 0-1 transition, and to lower velocities for multi-quantum transitions. During the past quarter a perturbation method has been explored to extend the range of validity of the calculations. The perturbation is that due to the spacial non-uniformity of the interaction force. For the exponential interaction used in Ref. 1 to represent N_2-N_2 collisions, this method extends the range of validity to $\sim 7 \times 10^5$ cm/sec (3.5 ev). A report is being written on this subject at the present time.

II. Vibration-Dissociation Coupling. Since molecular dissociation generally occurs from excited vibrational states, the rate of vibrational relaxation is important in determining the temperature dependence of the dissociation rate. The resultant coupling between vibration and dissociation has then been taken into account in an approximate way in the treatment of dissociation behind very strong shocks.[2,3,4] In these attempts a Boltzmann-like distribution (vibrational

"temperature") in vibrational energy has been assumed, but work done under the present contract[5] has shown that this assumption is violated for strong shocks. The extent of the departure from a Boltzmann distribution is important insofar as it affects the temperature dependence of the dissociation rate. The analytic investigation being performed under this portion of the present contract has verified that a strong non-Boltzmann distribution exists, and that it has a large effect on the dissociation rate. However, contrary to results obtained by assuming that a vibrational "temperature" could be defined, the effect on the dissociation rate has very little dependence on temperature. Thus the extrapolation of dissociation rates obtained at temperatures in the 4000-8000°K range to much higher temperatures would be independent of the vibration-dissociation coupling. Preliminary results for the ratio of the forward rate constant for dissociation of O_2 to that obtained for an equilibrium vibration distribution are shown in Fig. 1. This effort will be continued during the next quarter. The experiments to measure the non-Boltzmann distribution, discussed in the last progress report, are being postponed until the calculations are completed.

Bow Shock Calculations

During the past quarter, work was started on the generalization of the bow-shock program to handle non-symmetric bow shocks. It is expected that this new program will then be capable of producing flow fields in the stagnation region for bodies entering the atmosphere at angle of attack. This work will continue during the next quarter.

Vacuum Ultraviolet Radiation

Continued effort has been directed toward measuring the vacuum ultraviolet radiation from air in the 10 to 12,000 °K temperature range. All components for the multichannel spectrometer have been ordered, but delays have been encountered in procuring some of the optical components. The spectrometer chamber is being fabricated and will undergo vacuum testing by the end of June. The optics are being separately calibrated and will be installed directly after the vacuum checkout. The apparatus for windowless coupling to the shock tube is also being fabricated, and the fast cutoff valve involved was successfully tested to close in 5 milliseconds.

Completion of the new CAL shock tube intended for use in these studies has been delayed because of rework required to compensate for structural deficiencies in the tube design. These changes were found necessary when several components of the tube were damaged in preliminary hydrostatic pressure testing. It is planned to have the tube in operation by 1 July 1964, which will permit total-system checkout tests to be conducted shortly thereafter.

References

1. Rapp, D. and Sharp, T. E., J. Chem. Phys. 38, 2641 (1963).
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3. Treanor, C. E., Vibrational Relaxation Effects in Dissociation Rate-Constant Measurements. CAL Report AG-1729-A-1, August 1962.

4. Marrone, P. V. and Treanor, C. E., Phys. Fluids 6, 1215 (1963).

5. Treanor, C. E. and Marrone, P. V., Vibration and Dissociation Coupling Behind Strong Shock Waves. Dynamics of Manned Lifting Planetary Entry (Ed. S. M. Scala, A. C. Harrison and M. Rogers) John Wiley and Sons, Inc., 1963.

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